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Sources of Coal Reserve Data

Diane Skolits
Russell Lee

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SOURCES OF COAL RESERVE DATA

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OAK RIDGE NATIONAL LABORATORY
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SOURCES OF COAL RESERVE DATA*

Diane Skolits and Russell Lee

OVERVIEW AND ACKNOWLEDGMENTS

This report is a partially annotated bibliography of sources of coal reserve data and information for the United States. It draws upon other bibliographies, the most significant of these being:

Averitt, P., *Selected Summary Reports on United States and World Coal*, Unpublished, U.S. Geological Survey, 1981.

Energy Information Administration, *Demonstrated Reserve Base of Coal in the United States on January 1, 1979*, DOE/EIA-0289 (79) U.S. Department of Energy, Washington, D.C., 1981.

ICF Incorporated (Principal Investigators: Eyster, J. M., Klein, D. E., Walton, D. R.), *Coal Resource Information, Volume 2, Part 3: Bibliography*, EPRI EA-673, Electric Power Research Institute, Palo Alto, CA, 1980.

The following computer-retrieval bibliographies were also utilized:

DOE/RECON Energy Database (EDB), U.S. Department of Energy, Technical Information Center, Oak Ridge, TN.

ORBIT IV Files: Energyline, NTIS, generated by System Development Corporation's (SDC) International Search Service, 2500 Colorado Ave., Santa Monica, CA.

The references are divided into "General Sources," including those containing data for all or large portions of the United States, and into individual sections for each state. Items that are parts of recurring series are identified by an asterisk.

In addition to the above bibliographies, the authors conducted an independent survey of appropriate data sources and were assisted considerably by Frank J. Doyle and Thomas K. Matson of Maxima Corporation, Richard Bonskowski of the Energy Information Administration, and Carl H. Petrich and Edward L. Hillsman of Oak Ridge National Laboratory. They reviewed an initial draft of this report and made numerous helpful comments and suggestions on data sources that were omitted and on the style and content of the report. Any remaining errors or shortcomings are, of course, solely the responsibility of the authors.

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Attention was given primarily to those data sources having estimates of the *quantity* and *geographical location* of coal resources. Studies that report only on carbonizing properties, preparation characteristics, sulfur content or other analyses were not included. The report by P. Averitt, *Coal Resources of the United States, January 1, 1974,* U.S. Geological Survey Bulletin 1412, Washington, D.C., 1975, presents not only a good summary of information on coal quantity and distribution, but also one on coal classification. Figure 1, taken from the Averitt report, illustrates the classification of resources based on economic feasibility and geologic assurance and identifies several of the coal resource terms used in this bibliography.

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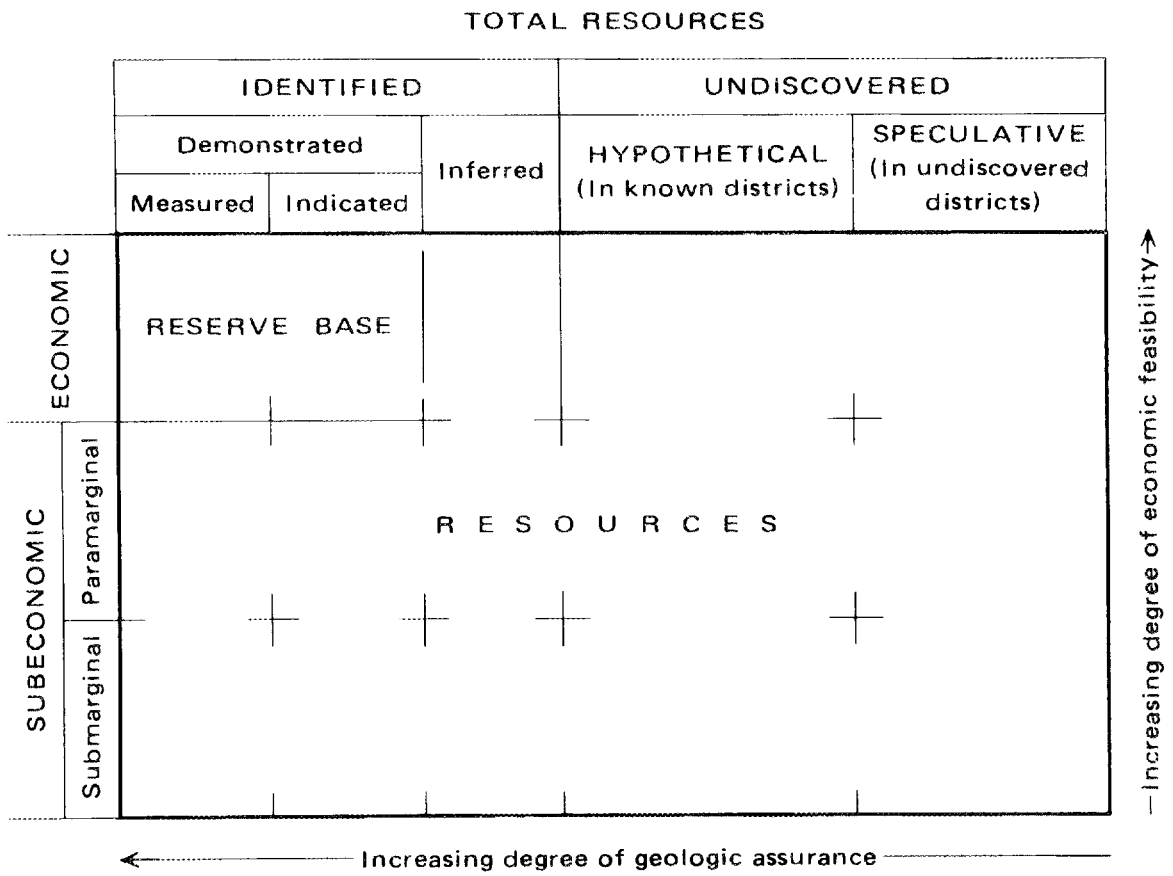

Fig. 1. Classification of coal resources. Source: Averitt, P., *Coal Resources of the United States, January 1, 1974,* U.S. Geological Survey Bulletin 1412, Washington, D.C., 1975, p. 3.

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SOURCES OF COAL DATA

GENERAL SOURCES

1. Ashley, G. H., *Cannel Coal in the United States*, U.S. Geological Survey Bulletin 659, Washington, D.C., 1918.

2. Averitt, P., Lopez, L., *Bibliography and Index of U.S. Geological Survey Publications Relating to Coal, 1882-1970*, U.S. Geological Survey Bulletin 1377, Washington, D.C., 1972.

3. Averitt, P., *Coal Resources of the United States, January 1, 1974*, U.S. Geological Survey Bulletin 1412, Washington, D.C., 1975.

   The coal resources of the United States remaining in the ground on January 1, 1974, are estimated to total 3,968 billion tons. This is a 23 percent increase over previous estimates. The new estimate is based on detailed published estimates of identified resources in individual states (1,731 billion tons) and on generalized estimates of additional hypothetical resources for unmapped and unexplored areas in these states (2,237 billion tons). The United States contains about 20 percent of the world's estimated total coal resources. Based on a uniform Btu basis, coal constitutes 69 percent of the total estimated recoverable resources of fossil fuel, whereas petroleum and natural gas together constitute only 7 percent, and oil in oil shale — which is not currently used as fuel — constitutes only 23 percent.

   Previous publications by the U.S. Geological Survey with similar titles and scope of coverage are: Bulletin 1275 (January 1, 1967), 1969; Bulletin 1136 (January 1, 1960), 1961; Circular 293 (January 1, 1953), 1953; and Circular 94 (January 1, 1950), 1950. The U.S. Geological Survey is currently working on an update.

4. Averitt, P., *Coking-Coal Deposits of the Western United States*, U.S. Geological Survey Bulletin 1222-G, Washington, D.C., 1966.

5. Averitt, P., *Stripping-Coal Resources of the United States, January 1, 1970*, U.S. Geological Survey Bulletin 1322, Washington, D.C., 1970.

6. Barnes, F. F., *Coal Fields of the United States, exclusive of Alaska-Sheet 2*, U.S. Geological Survey Map, Scale 1:5,000,000, 1961.

7. Bureau of Mines, *Reserve Base of Bituminous Coal and Anthracite for Underground Mining in the Eastern United States*, Report No. BM-IC-8655, Pittsburgh, PA, 1974.

   The coal reserve base is defined for coalbeds having sufficient thickness for underground mining within a depth range compatible with economic recovery. The reserve data are compiled by the Federal Bureau of Mines by updating and reevaluating previous

estimates of the U.S. Geological Survey, state geological surveys, and others. Through the application of computer techniques, the tonnages are compiled by state, county, coalbed, and rank. Coal reserve base is allotted to sulfur categories by a statistical apportionment of data from available Bureau of Mines reports and records. The coal reserve base in those states east of the Mississippi River, minable by underground methods, is estimated to be 169 billion tons in coalbeds greater than 28 inches in thickness to a maximum depth of 1,000 feet. Excluding those coals in reliability categories other than measured and indicated, the underground reserve base includes 162 billion tons of bituminous coal and 7 billion tons of anthracite. Of the total, 27 billion tons contains 1.0 percent or less sulfur. Most of this low-sulfur coal is in the southern Appalachian area. Approximately 16 percent of the underground reserve base is without available analyses. A glossary of terms applicable to a classification system for coal resources and reserves is included to provide a common yardstick for determining coal resources and reserves.

8. Burness, H. S., *The Effects of Uncertainty on the Supply of Coal*, University of Kentucky, College of Business and Economics, Report No. PB-277227, June 1976.

9. Cargill, S. M., Olson, A. C., Medlin, A. L., Carter, M. D., *PACER: Data Entry, Retrieval, and Update for the National Coal Resources Data System (Phase I)*, Department of the Interior, Washington, D.C., 1976.

   PACER is a set of programs, written in Fortran IV, which has been developed in response to the need for a computer-based National Coal Resources Data System (NCRDS). PACER allows the user to enter data into one of three files, to search for and retrieve records using specific data elements, and to modify and update existing data records. All coal resource records west of the Mississippi River are grouped into WCOAL; those east of the river are grouped into ECOAL. Each data record in WCOAL and ECOAL reflects a unique tonnage estimate of coal resource in a predefined category of thickness, overburden, and reliability of estimate. The USALYT file contains published coal analytical data and is structured to be as compatible as possible with the coal-resource tonnage files; however, it is not yet been separated into east and west. A detailed description of the files is accompanied by user documentation for the use of the data files. A programmer's reference is also included to facilitate the installation and use of this software system on other computers.

10. Carter, L. M., ed., *Proceedings of the Fourth Symposium on the Geology of Rocky Mountain Coal*, Colorado Geological Survey Resource Series 10, 1980.

11. Cavallaro, J. A., Johnston, M. T., Deurbrouck, A. W., *Sulfur Reduction Potential of the Coals of the United States* (A Revision of Report of Investigation 7633), U.S. Bureau of Mines Rept. of Investigations 8118, 1976, 323 pp.

12. Center for Advanced Computation, University of Illinois, *Comparative Coal Transportation Costs: An Economic and Engineering Analysis of Truck, Belt, Rail, Barge and Coal Slurry and Pneumatic Pipelines,* Final Report on Contract No. J0166163, prepared for U.S. Bureau of Mines and Federal Energy Administration, August 1977.

13. Coal Age, Appalachian Coal Today, *Coal Age,* v. 80, no. 6, pp. 55-316, Mid-May 1975.

14. Coal Age, Western coal, *Coal Age,* v. 78, no. 5, pp. 58-257, Mid-April 1973.

15. Collins, B. A., "Coal Deposits of the Eastern Piceance Basin, Mid-Continent Coal and Coke Co., Carbondale, Co.," *Geology of Rocky Mountain Coal,* Murray, D. K. (ed.), 29-44, Geology of Rocky Mountain Coal, Golden, CO, 1977.

The coalfields of the Eastern Piceance Creek Basin contain a conservatively estimated 3,129 million tons of bituminous coal and anthracite. At least 800 million tons are of metallurgical quality. These coals occur in the Iles and Williams fork formations, which together make up the Mesaverde group. Rank varies from high-volatile C bituminous to anthracite and, locally, graphite. While those coals occurring north of Four Mile Creek owe their rank entirely to depth of burial, the higher-rank coals south of Four Mile have been subjected to abnormally high geothermal gradients, the result of heat from the intrusions of the Elk and West Elk mountains. The coking quality of the coals, while secondarily dependent on peat type and swamp conditions, is primarily a function of rank. Large-scale mining is presently limited to the coking coals in the southern part of the area. Modern mining in much of the rest of the region awaits the development of economic methods to cope with steep formation dips and other geologic problems.

16. Comptroller General of the United States, *U.S. Coal Development — Promises, Uncertanties,* Report to the Congress, EMD-77-43, Sept. 22, 1977, 471 pp.

Coal represents 90 percent of the nation's total fossil fuel reserves. Yet, it currently supplies only 18 percent of energy needs. The administration proposes to double annual coal production to 1.2 billion tons by 1985, up from 665 million tons in 1976. GAO believes that achieving 1.2 billion tons is highly unlikely — in fact, it will be very difficult to achieve 1 billion tons annually by 1985. In this report, GAO summarizes available knowledge on U.S. coal development and seeks to identify policy issues that must be considered.

17. DeCarlo, J. A., Sheridan, E. T., Murphy, E. E., *Sulfur Content of United States Coals,* U.S. Bureau of Mines Inf. Circ. 8312, 1966.

Nearly two-thirds of the total remaining coal reserve of the United States is low-sulfur coal. Roughly three-fourths of this low-sulfur coal is low rank (subbituminous and lignite). The preponderance of low-sulfur coal, on a tonnage basis, occurs west of the Mississippi River.

18. Fettweis, G. B., *World Coal Resources — Methods of Assessment and Results,* Elsevier Scientific Publishing Co. Developments in Economic Geology 10, 1979.

19. Foster Associates, Inc., *An Assessment of the Discrepancies in United States Low Sulfur Coal Reserve Estimates,* Prepared for Environmental Protection Agency, Research Triangle Park, Durham, North Carolina, Contract No. 68-02-1452, 1976, Volume 1 — Text, Volume 2 — Schedules and Charts.

20. General Accounting Office, *Inaccurate Estimates of Western Coal Reserves Should Be Corrected,* Report to the Congress, Washington, D.C., Energy and Minerals Division, 11 July 1978, 63 pp.

An accurate estimate of coal under federal lease and information on lessee development plans are essential for supporting coal leasing policy decisions. Better estimates are needed to relate interior leasing with the administration's goal of increasing domestic coal production. Interior's recoverable reserve estimates are based on general recovery factors, not on detailed, current economic analysis; using unreliable estimates in enforcing laws would produce inadequate production controls, increase the chances for speculative holdings, and be against the public interest. Wide variations existed between Interior and leaseholder estimates; leaseholder estimates were generally supported better. But many leaseholder estimates were incomplete because they did not consider all underground coal. GAO considers neither Interior nor leaseholders estimates accurate or reliable. No coal was produced before 1977 on most federal leases; about 212 million tons may be produced annually by 1985.

21. Gordon, R. L., Schenck, G. H. K., *Historical Trends in Coal Utilization and Supply,* U.S. Bureau of Mines Open File Rept., 121-76, 1976, 631 pp. (NTIS PB 261 278/AS)

The Bureau of Mines provided a research grant to Pennsylvania State University to examine in detail the historical behavior of coal consumption and the forces that are affecting prospective coal use, and to provide various scenaries of future consumption in selected markets. The study made three basic contributions in the areas it treated. First, it consolidated and analyzed available historical data on the role of coal in the U.S. energy economy. Second, the proliferation of materials analyzing the forces affecting coal market developments was synthesized. Third, an effort was made to delineate possible patterns of future coal use.

22. Hamilton, P. A., White, D. H., Jr., Matson, T. K., *Reserve Base of U.S. Coals by Sulfur Content (in two parts), The Western States,* Bureau of Mines, Information Circ. 8693, Denver, Colo., 1975.

This report delineates the coal reserve base of anthracite, bituminous and subbituminous coals, and lignite, by mining method and sulfur content, for coal-bearing states west of the Mississippi River. The parameters used to establish the reserve base definition are the result of a joint agreement by the U.S. Bureau of Mines and the U.S. Geological Survey. The reserve base of low-sulfur coal, less than or equal to 1.0 percent sulfur, is 167,324.5 million tons; medium-sulfur coal, 1.1 to 3.0 percent sulfur, is 37,531.5 million tons; and high-sulfur coal, greater than 3.0 percent sulfur, is 11,244.1 millions tons. The reserve base of coal with an unknown sulfur level is 18,323.0 million tons. The percentages of deep and strippable coal are 56 and 44 percent, respectively. The basis for reserve base estimates and analytical data was the fuels availability system, a Bureau of Mines Data Bank containing numerous data on fossil fuels. Information contained in the system was obtained from publications of the Bureau of Mines, U.S. Geological Survey, state agencies, private publications, and company data.

23. Hodgson, H. E., ed., *Proceedings of the Second Symposium on the Geology of Rocky Mountain Coal, 1977,* Colorado Geological Survey Resource Series 4, 1978, 219 pp.

24. International Geological Congress, 12th, *The Coal Resources of the World,* Toronto, Canada, Morang and Co., 3 v., 1913.

*25. *International Journal of Coal Geology,* Elsevier Scientific Publishing Company, vol. 1, no. 1, 1980. Published quarterly.

26. Kahn, M. H., Hahn, R., *Implications of Ownership Patterns of Western Coal Reserves and Their Impact on Coal Development,* Mitre Corporation, Report No. MTR-7249, 1976.

27. Klein, D. E., *Revised Coal Resource Estimates — Four Case Studies,* Electric Power Research Institute, EPRI-EA-1360., Palo Alto, CA.

This report presents analyses undertaken to revise coal resource estimates for modeling purposes. The areas covered herein are in ICF's Coal and Electric Utilities Model (CEUM). The coal supply curves are developed as a function of coal reserves and mine-costing algorithms. The slope and length of the coal supply curves depend upon the coal reserve data and the assumptions used to allocate the reserves across mine types. In CEUM, the source of the coal reserve data is the Bureau of Mines Demonstrated Reserve Base (DRB). The DRB is generally considered to be the most comprehensive set of coal reserves data available which covers the entire U.S. However, it has some distinct characteristics and weaknesses which limit its usefulness for modeling and forecasting. As a

response to these actual or potential weaknesses in the DRB, this study seeks to improve upon the coal resource estimates used in the modeling work. Here, ICF is seeking to refine the shapes of the coal supply curves as well as to extend them to include less economic resources. In refining the shapes of the coal supply curves, the emphasis is on non-tonnage information; e.g., overburden ratios, seam thickness, coal quality, etc. In extending the coal supply curves, the emphasis is on incorporating less desirable and/or certain resources which are not included in the DRB. Illinois, Texas lignite, Alaska, and Campbell County in Wyoming were selected as the initial areas for analysis for several reasons. Each area has large coal resources, and future production from these regions is highly sensitive to several factors. Production from these regions also has a major impact on the production from other regions. Finally, for each area, additional information is known to be available, which could substantially improve the accuracy and/or completeness of the DRB estimates.

28. Kottlowski, F. T., Cross, A. T., and Meyerhoff, A. A., eds., *Coal Resources of the Americas — Selected Papers,* Geological Society of America Spec. Paper 179, 1978.

29. Land, G. W., *Reality of Coal Availability,* Amax Coal Company, Indianapolis, IN, 3 October 1974.

30. Lee, R., Bradfield, L. D., Howard, B. R., Latham, F. E., Skolits, D., *Coal Supply Analysis for the Office of Environmental Programs Issues Analysis,* Draft Report, Energy Division, Oak Ridge National Laboratory, 1982.

31. Luppens, J. A., *Exploration for Gulf Coast United States Lignite Deposits: Their Distribution, Quality, and Reserves,* Second Intern. Coal Exploration Sym., Denver, Colo., October 1-4, 1978, 16 pp.

    The total estimated strippable in-place lignite reserves for the Gulf Coast region are 22.5 billion short tons.

32. Markon, G., *United States Coals in World Markets,* U.S. Bureau of Mines Inf. Circ. 8380, 1968, 87 pp.

33. Masters, C., *Coal Data System: Its Purpose and Value,* U.S. Geological Survey, Reston, VA, Future Coal Supply for the World Energy Balance, pp. 100-113.

    To allow rapid retrieval as well as ease of update and analysis of data on coal quantity and quality, a computer-based coal-resource data system has been developed by the branch of coal resources within the U.S. Geological Survey. Development has been in two phases to accommodate the availability and complexity of the data.

34. Matson, T. K., *Preliminary Estimate of the Demonstrated Reserve Base of Coal on Indian Reservations,* U.S. Bureau of Mines, Washington, D.C., 1976.

Preliminary estimates indicate that coal in Indian reservations totals approximately 18.6 billion tons, constituting on the order of 4 percent of the demonstrated reserve base of coal available for mining in the United States, remaining as of January 1, 1976. This estimate is for coal on Indian reservations west of the Mississippi River; there is no known coal of minable thickness on Indian reservations in the eastern part of the United States. Therefore, the above estimate would indicate that on the order of 8 percent of the demonstrated reserve base of coal west of the Mississippi River lies within the boundaries of Indian reservations. Breaking this down further, Indian reservations appear to contain nearly 7 percent of the demonstrated reserve base of surface-minable coal in the west, and 5 percent for the total United States. The comparable proportions for underground-minable coal are 9 percent and 4 percent, respectively.

35. Matson, T. K., White, D. H., Jr., *Reserve Base of Coal for Underground Mining in the Western United States,* U.S. Bureau of Mines, Washington, DC, and Publications Distribution Center, U.S. Bureau of Mines, Pittsburgh, PA, 1975.

The coal reserve base in the western United States is presented for coalbeds amenable to extraction by underground mining methods. The U.S. Bureau of Mines has abstracted data on the quality and quantity of coal resources/reserves from numerous state and federal publications and modified such data as necessary to allow computer storage and retrieval. Tonnages are compiled by state, county, coalbed, and rank, and allotted to sulfur categories by statistical apportionment. The coal reserve base in those states west of the Mississippi River, amendable to underground mining, is estimated to be approximately 131 billion tons. Of this total, about 30.8 billion tons are bituminous coal, 100.2 billion tons are subbituminous coal, and 126.4 million tons are anthracite. Lignite is not considered for underground mining in this report. Included in this report is a glossary of terms applicable to a classification system for coal resources and reserves as jointly defined by the Bureau of Mines and U.S. Geological Survey. The purpose of this system is to provide for direct comparison or compilation of various resource/reserve data.

*36. McGraw-Hill, Inc., *Keystone Coal Industry Manual,* New York, McGraw-Hill Mining Informational Services. Published annually.

*37. McGraw-Hill, Inc., *U.S. Coal Mine Production by Seam*, Keystone Coal Industry Manual, 1980.

38. McNulty, J. E., Ball, C. G., *Coal Reserves: Estimates*, Paul Weir Company Incorporated, Chicago, Energy Technology Handbook, Considine, D. M. (ed.), 1977.

Data on the location of U.S. and worldwide coal reserves are given.

39. Muir, W. L. G., *Review of the World Coal Industry to 1990*, Miller Freeman Publications Ltd., Circle House North, 69-71 Wembley Hill Road, Wembley, Middlesex, England HA9 8BL, 1975.

40. Murchison, D., Westoll, T. S., *Coal and Coal-Bearing Strata*, American Elsevier Publishing Co., New York, 1968, 418 pp.

41. Murphy, Z. E., *Assessment of Coal Resources*, CONF-770136, Bureau of Mines, Washington, DC, Conference on Coal Production, Use, and Financing, Section 2, Paper 1, Washington, DC, January 25, 1977.

Until recently there had been little incentive to categorize in detail our vast coal resources. With increasing limitations being placed on coal production and use, and with the realization in recent years that we must expand greatly both production and use of coal, the need for more detailed appraisals of our coal resources has become apparent. A new resource classification system adopted by the Bureau of Mines and the U.S. Geological Survey should assist both in making these appraisals and in a public understanding of them. Already, the Bureau of Mines has used this system to classify coal resources according to geographic distribution; coalbed; and sulfur, ash, moisture content, and heating values.

*42. National Coal Association, *Coal Facts, 1974-1975*, National Coal Association, Washington, D.C., 1975. (Published biennially for 26 years prior as *Bituminous Coal Facts*).

43. National Coal Association, *Coal Data, 1977*, National Coal Association, Washington, D.C., 1979.

44. National Coal Association, *International Coal, 1979*, National Coal Association, Washington, D.C., 1980.

45. Northern Great Plains Resources Program, *Mineral Resources Work Group Report*, 1974.

46. Noyes, Robert, ed., *Coal Resources, Characteristics, and Ownership in the U.S.A.*, Noyes Data Corporation, Park Ridge, New Jersey, 1978, 346 pp.

47. Parker, N. A., Thompson, B. C., *U.S. Coal Resources and Reserves*, Federal Energy Administration, Office of Policy and Analysis, Office of Data and Analysis, Office of Coal, Nuclear, and Electric Power Analysis, Report No. PB-252752, FEA/B-76/210, 1976.

The extent and quality of coal resources and reserves in the U.S. are described in this article. Different categories of coal resources are defined and the extent of coal in each category is estimated. The content of sulfur in coal is discussed with respect to environmental standards. Data are presented on coal reserves on federal and Indian lands, areas containing a large percentage of the country's reserves. Because coal is the largest fossil fuel resource in the U.S., its importance will continue to increase. With 40% of the nation's total coal reserve located on federal lands, the federal government is expected to play a significant role in future coal development. A large portion of U.S. coal resources contains too much sulfur to meet environmental regulations. Improvements must be made in sulfur removal technologies in order for this nation to fully exploit its extensive coal resources.

48. Popoff, C. C., *Computing Reserves of Mineral Deposits: Principles and Conventional Methods*, U.S. Bureau of Mines Information Circular 8283, 1966.

49. Rees, P. B., *Establishing the Reliability of Deep Coal Reserves*, Sixth Intern. Mining Congress, Great Britain, 1970.

50. Reese, R. G., Dash, B. B., Hamilton, P. A., *Coal Recovery from Underground Coal Mines in the United States by Mining Method*, U.S. Bureau of Mines Inf. Circ. 8785, 1978.

51. Rieber, M., Soo, S. L., Stukel, J., *Low Sulphur Coal: A Revision of Reserve and Supply Estimates Appendix C. Final Report*, Illinois University, Urbana, Center for Advanced Computation, PB-248062, 1976.

Conventionally, the definition of low-sulfur coal, on which traditional reserve and supply estimates are based, depends only on the weight of sulfur in a ton of coal. The Btu content of the coal is not considered. Coal purchases and SO_2 regulations are based on Btu content. A recalculation of reserve estimates of low-sulfur coal on a utility average Btu basis reduces traditional U.S. estimates by over 75 percent and western estimates by almost 85 percent. When calculated on a Btu basis, maximizing low-sulfur coal production results in a supply shortage by 1986. The policy implications for an increased dependence on domestic coal include increased cleaning of high-sulfur coal and export limitations on low-sulfur coal in the short-term. In the mid-term, large capital expenditures in processes which reduce or eliminate the sulfur content are required. These include stack gas scrubbing, gasification and liquefaction. For the consumer, some of these costs can be offset by the elimination of the transportation charge differential between local high-sulfur coal and coal from Wyoming, Colorado, and Montana.

52. Sanner, W. S., and Benson, D.C., *Demonstrated Reserve Base of U.S. Coals with Potential for Use in the Manufacture of Metallurgical Coke*, U.S. Bureau of Mines Information Circular 8805, 1979.

53. Schmidt, R. A., *Coal in America: An Encyclopedia of Reserves, Production and Use,* New York, McGraw-Hill Book Co., 1979.

54. Scollon, T. R., "Assessment of Coal Resources," *Chem. Eng. Proc.* V. 73, No. 6, pp. 25-30, June 1977.

This paper presents data related to coal deposits in the United States. The reserve base indicates at least 219 billion tons, or 300 years of coal. At the rate we are using it now, details of deposit locations and of their usability as an energy resource are given. The Interagency Coal Task Force of Project Independence Blueprint determined in 1974 that coal production could reach 1.2 billion tons by 1985 with the relaxation or removal of constraints limiting the expansion of coal production and use.

55. Secor, E. S., and others, *Coal Recovery From Bituminous Coal Surface Mines in the Eastern United States, A Survey,* U.S. Bureau of Mines Inf. Circ. 8738, 1977, 14 pp.

56. Sheridan, E. T., Markon, G., *Supply and Demand for United States Coking Coals and Metallurgical Coke with a Section on Foreign Trade in Coking Coals,* Special pub., Bureau of Mines, Washington, DC, BM-SP-9-76, December 1976, 30 pp.

This report gives the known quantities of premium-grade coking coals in each state and compares estimated current production of coking coals with the requirements of domestic coke producers. Also, demand for metallurgical coke in the United States in 1985 is projected.

57. Smith, G. E., "Regional Coal Resource Update," Institute for Mining and Minerals Research, Lexington, KY, in *Gas From Coal for Industry: Direct Utilization of Coal, Problems and Solutions,* Hahn, O. J., MacClellan, D. T., De Vore, R. W. (eds.), pp. 9-10.

58. Smith, W. H., "Computer Evaluation and Classification of Coal Reserves," in *Coal Exploration,* Muir, W. L. G. (ed.), pp. 450-462, Miller Freeman Publications, Inc., San Francisco, 1976.

It is now possible to store in a data bank and later retrieve in map format all of the data concerning a mining operation that is required for land management, geological evaluations, and mining engineering. This mapping requires a coal data base containing all the specific information obtained during the exploration and evaluation program. The build-up of this base is described with its storage and retrieval system. The calculation of coal reserves by computer and the method of excluding areas in which the seam is too thin or absent are described. Reserves can be classified, for example, by ash or sulfur content. Conversion of existing records to establish a fully integrated coal data base capable of producing structure contour maps, coal isopach maps, and complete reserve estimates will take some time but can be built up a module at a time.

59. Spearman, J. E., *The United States Metallurgical Coal Industry — Reserves, Efficiency, Outlook,* West Virginia University Press, Morgantown, 1980.

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The Bureau of Mines contracted with HRB-Singer, Inc., State College, Pennsylvania, for the development and implementation of a methodology for estimating the impact of coal seam interaction on the eastern bituminous underground reserve base. The effects of previous mining in multiple coal seam areas on currently mined and reserve seams are predicted as a percentage coal loss by an engineering assessment model called the Coal Loss Calculation Model. The model utilizes 12 input variables easily derivable from mine maps or other existing data sources and calculates the effects of subsidence and high stress due to remnant pillars in the previously mined seam.

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The coal resource investigations of the U.S. Geological Survey are directed towards the mission of helping alleviate the energy crisis by developing information immediately usable by the government, industry, and the public. Individually and collectively, the investigations are aimed at assessing the location, size, quantity, and quality of the coal deposits of the nation so that the proper coal can be mined at the most effective locality for the correct usage. In support of this assessment some of the investigations are directed to developing data on the origin of coal, the phenomena and processes that controlled coal accumulation, and the chemical and physical characteristics of regional and local coal deposits so that the location and distribution of undiscovered deposits may be predicted; to developing and maintaining a computerized data system capable of assessing and updating estimates of the nation's coal resources; and to developing the scientific ability to predict geologically pertinent facts concerning coal with a minimum of exploratory effort. The description of the Geological Survey's coal resource investigations is presented in the context of the underlying socio-economic problem of expanding the domestic production of coal while maintaining acceptable environment standards. A bibliography of individual projects, appropriate fiscal data and an outline of procedures involved are included in appendices.

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This report considers the manner by which land use and land ownership patterns may reduce the availability of coal reserves. The applicability of various information sources for such a study is examined, and a methodology is outlined in which land use, surface ownership, and mineral ownership data may be collected and interpreted at the county level. A variable-scale grid mapping system was devised to display the interrelationships between surface land use, ownership, and the distribution of coal deposits. This methodology was then used to analyze potential coal availability within Monongalia County.

95. Zimmerman, M. B., *The Supply of Coal in the Long Run: The Case of Eastern Deep Coal*, Massachusetts Institute of Technology, Energy Laboratory, Report No. MIT-FL 75-021, 1975.

Examination of costs and reserves of coal to determine mineral reserves indicates that natural depletion, technological developments, and policy decisions must all be taken into account. Previous analyses using only a demonstrated reserve base of seam thickness do not give an accurate figure. Costs will be affected by shifts to deep mining and low-sulfur coal mining for environmental reasons. Technological developments in mining engineering, processing, and stack cleaning will also affect costs. Other factors will be user response in terms of demand and substitution of other fuels, and rising labor costs. Rates of cost increases will be determined by the length of time given for adjustment.

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SOURCES FOR INDIVIDUAL STATES

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   Methods by which estimates of the remaining reserves of strippable coal in Alabama could be made were developed. Information acquired from NASA's Earth Resources Office was used to analyze and map existing surface mines in a four-quadrangle area in west central Alabama. Using this information and traditional methods for mapping coal reserves, an estimate of remaining strippable reserves was derived. Techniques for the computer analysis of remotely sensed data and other types of available coal data were developed to produce an estimate of strippable coal reserves for a second four-quadrangle area. Both areas are in the Warrior coal field, the most prolific and active of Alabama's coal fields. They were chosen because of the amount and type of coal mining in the area, their location relative to urban areas, and amount and availability of base data necessary for this type of study.

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   The Warrior Coal Basin is the southwest end of the visible coal measures of the Warrior coal field. The basin is made up of shales, sandstones, conglomerates, and stone coals. The shales and sandstones are from the great bulk of the strata. The coals are from 2 to 5 regular seams in each of 6 groups. The groups are the Black Creek, Horse Creek, Pratt, Cubb, Gwin, and Brookwood. The Horse Creek and the Pratt are the principal groups. The coal seams range in thickness from a few inches to some 16 feet. Most of the coal can be mined with ease and cheapness. The coals, though all bituminous, are of various kinds.

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9. Self, D. M., *Lignite Resources of the Alabama-Tombigbee Rivers Region, Alabama.* Consolidated Coal Co., Meridian, Mississippi, CONF-7606131, Proceedings Gulf Coast Lignite Conference: Geology, Utilization, and Environmental Aspects. Report of Investigations No. 90, Kaiser, W. R. (Ed.), pp. 59-65, Austin, Texas, June 2, 1976.

The lignite resources of the Alabama-Tombigbee Rivers region of southwest Alabama exceed 4.7 billion short tons. Near-surface deposits having economic potential occur in the Oak Hill member of the Naheola formation and the Upper unnamed member of the Tuscahoma formation. Demonstrated reserves in the near-surface amount to approximately 562 million short tons. The near-surface lignite in the Oak Hill member generally occurs as a single tabular bed which ranges from 1 to 14 ft in thickness. Moisture and sulfur content are high; however, ash content is low, and the calorific value may exceed 11,200 Btu/lb on a moisture-free basis.

The lignite of the Tuscahoma formation occurs in from one to six beds and is generally inferior to the Oak Hill lignite. The ash content is very high, and the calorific value is correspondingly low. Deep-basin deposits occur in the Midway and Wilcox groups; however, only the Midway lignites appear to have economic potential. Demonstrated and inferred resources in deep-basin deposits total over 4.1 billion short tons. The lignite of the Midway group occurs in one to three beds which are apparently equivalent to the near-surface lignite of the Oak Hill member.

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A study was made of the coal resources of an area in Jackson County, Alabama, forming a part of the Flat Rock, Henegar, and Stevenson quadrangles. The area studied is a portion of the Plateau coalfield on Sand Mountain and is near the Tennessee Valley Authority's Widows Creek Steamplant. Since no detailed geological study of this area had been published, some reconnaissance work was done. The coalbeds and adjacent strata such as sandstones, conglomeratic sandstones, and conglomerates were studied. Available drill logs, together with the areal geology, provided sufficient information to permit correlations of the coalbeds and an estimation of coal reserves. For all categories of reserves, computed on a regional

basis, a total of 72,920,000 tons of coal more than 14 inches thick is estimated for the areas studied in the Stevenson, Flat Rock, and Henegar quadrangles. Of this tonnage, 40,0001,000 tons is estimated to have less than 60 feet of overburden. The total measured coal reserves for the above three quadrangles are 16,359,000 tons, with 12,471,000 tons under less than 60 feet of cover.

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This is the sixth of a series of reports prepared to portray the coal fields served by the Southern Railway system and its short-line connections. The previous reports presented data on Kentucky, Illinois, Indiana, Virginia, and Tennessee. Estimates of the coal reserves present in the various areas are based upon the latest available computations made for each area by governmental and private agencies. The figures have been estimated as of 1964 with newer data reflecting estimates made in 1969. The estimates have been made for recoverable coal reserves in each seam by county and coal field for Alabama. The seams included are those which can reasonably be considered as mineable and recoverable within the area served by Southern Railway system. The figures reported are recoverable tons based on the average thickness of the coal seam in each area. The recoverability of coal in mining is perhaps the largest single factor influencing the magnitude of reserves. In this report, it has been assumed that only 50 percent of the coal in the ground will be recovered by conventional mining methods.

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9. Marstrander, H., Apell, G. A., Rutledge, F. A., Hulbert, J. H. *Exploration of Leasing Block No. 28 in the Nenana Coal Field, Alaska.* Bureau of Mines, Washington, D.C., 1946.

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   Little coal has been mined in California for 30 years, though the estimated resources of 90.7 million metric tons [Averitt, 1975, p. 43 (listed under "General Sources")] has caused a resurgence of interest in its potential during the energy crisis of the 1970s. The occurrence of coal has been reported in 43 of the 58 counties of California; the major coal-bearing areas are shown in Figure 1. Generally, coal beds are of Cretaceous to Pliocene and Pleistocene age and range in thickness from less than 1 meter (m) to about 7 m. The rank of coal ranges from lignite to high-volatile B bituminous coal. Thirty-five references concerning coal deposits in California are annotated in this bibliography. These reports are considered to be the most comprehensive of more than 130 references available on coal deposits in California. Current (1978) stratigraphic information has been added to the text in brackets where appropriate. Reports on coal published prior to 1922 were listed in a bibliography compiled by Boalich (1922) — and some of these reports are annotated in the present bibliography.

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COLORADO

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Coal mining began in Colorado in the early 1860's. Since then, the 1667 mines located by the authors have produced a total of 598,824,876 short tons of coal to January 1, 1977. This activity has depleted the reserve base of Colorado by 1,160,752,484 short tons. Most of the coal produced to date has been mined from beds ranging from 4 to 10 ft in thickness. Using original reserve base estimates calculated by the U.S. Department of Energy (Matson, 1979), 6.67 percent of the State's demonstrated coal reserve base has been produced or lost in the process of mining. This leaves 93.33 percent of the original reserve base intact. Estimates of the remaining demonstrated coal reserve base for each coal-bearing region are given. During the two-year period, 1977-1978, the main producing region, the Green River, produced 15,405,488 short tons, or 58.62 percent of total two-year statewide production of 26,279,491 tons. This high figure is the result of large surface mining operations in the area. Coal has been produced from all of the coal-bearing regions in Colorado. This report is an attempt to determine how much coal has been mined or otherwise rendered unavailable to mining and from what coal zones this production has been obtained. The data presented are preliminary in nature; however, this report does represent a concise summary of certain aspects of the coal mining history of Colorado. The authors hope that this project will result in more efficient future development and production of coal in this state.

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Certain coals from the State of Colorado have long served as a major component for the manufacture of coke. However, decision-makers both in private industry and in all levels of government have been hampered by the lack of comprehensive and detailed statewide coking-coal resource evaluation. To alleviate this problem a two-year project was initiated to evaluate the resources of coking coal in Colorado. Based on a precedent set by workers in the U.S. Bureau of Mines and Department of Energy, a classification system was established to evaluate coking-coal resources in Colorado. This classification system uses coal ash and sulfur content and ASTM rank designations to categorize coal resources as being either

premium (0-1.0% S, 0-8.0% ash), marginal (1.1-1.8% S, 8.0-12.0% ash), or latent (1.9-3.0% S, 12.1-15.0% ash) grade coking coal. Using this classification system, coal regions were selected as areas containing potential coking-coal reserves. Identified original, in-place, coking-coal reserve estimates then were made utilizing the proposed coking-coal classification system, coal resource evaluation maps, and published coal reserve estimates. In Colorado, the Raton Mesa region contains 2.05 billion short tons, the San Juan River region 1.78 billion short tons, and one Uinta region 0.45 billion short tons of identified coaking-coal reserves. The total identified original in-place coaking-coal reserves for the state of Colorado are estimated at 4.3 billion short tons.

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Coal-bearing areas by depth, quality, and classification; estimates of original and remaining resources; active, abandoned, and proposed

surface and underground mines; production figures for individual major mines; current and proposed utility plants, coal treatment plants and coal conversion plants.

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The Denver and Cheyenne basins are major coal- and lignite-bearing regions in Colorado. About 36% of the area within Colorado that is underlain by coal at a depth of less than 8000 ft (900 m) is within these two basins. Subbituminous coal and lignite occur in the Upper Cretaceous Laramie formation and lignite occurs in the Upper Cretaceous – Paleocene Denver formation. A total of 130,196,330 tons of coal and lignite have been mined from these two formations in the Denver and Cheyenne basins; about 20 to 25 billion tons of Laramie formation coal and 10 to 15 billion tons of Denver formation lignite remain in place in the study area. This report presents a part of the first-year findings from a 2.5-year study of the environmental impacts of energy-resource development in the area. A primary goal of the investigation is to develop a thorough understanding of the various environmental impacts that may result from energy resource development. Another goal is to identify areas underlain by valuable energy resource deposits, both fossil fuel and uranium, that need to be protected from alternate land uses that may prohibit or inhibit future resource development. Detailed geological information is provided on 5 plates in this packet. Plate 1 contains data on the Laramie formation coal, Denver and Cheyenne basins; Plate 2, Denver formation lignite, Denver Basin; Plate 3, Watkins area, Adams and Apapahoe counties; Plate 4, Station Creek area, Elbert County; and Plate 5, cross sections of the Denver formation lignite beds, Denver Basin.

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The southeastern part of the Laramide Piceance Creek Basin is one of the most important coal-producing areas in the western U.S. This also is a region of accelerated exploration for natural gas.

The upper Cretaceous Mesaverde Group contains the major coal beds and gas-bearing sandstones found in this part of Colorado; these strata are part of a sequence of marine, transitional, non-marine sediments. These complex rock units are of possible Deltaic and/or Coastal Plain origin and represent east-west oscillations of the late Cretaceous Seaway. Numerous tertiary intrusive bodies and related structural complexities characterize the eastern part of the area investigated. Adnormally high heat flow resulting from this plutonic activity has raised the rank of much of the coal that occurs here. As a consequence, the region contains large resources of premium-grade coking coal, much of it existing under deep cover (greater than 1,000 ft) and often high in methane gas content. Most of the area's production consists of coking coal from underground mines. Several new mines of large capacity are in the planning or opening stages, which could result in an increase in the region's production of both coking and steam coal by a factor of two or three by 1980-1982. The large results of lower rank (high-volatile C bituminous) steam coal in the area offer an excellent potential for blending with high rank coals to form the metallurgical coke. The region contains large resources of methane gas that should be commercially producible from both relatively "tight" sandstone reservoirs and from fractured coal beds by employing advanced technology now in the field demonstration stage. Work to date reveals that multiple, thick (20-50 ft) coal beds occur in the basin at depths exceeding 3,000-7,000 ft. This deep energy resource possibly could be exploited by the in-situ gasification of coal beds, whereby low-Btu gas is produced through boreholes.

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Coal-bearing areas, coal leasing areas, oil and gas fields, uranium and geothermal areas, and existing and proposed coal mines and power plants.

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Coal analyses, rank, coking properties, current and projected future production, market areas, transportation, utilization, ownership of coal lands, taxation, and import-export statistics. Supersedes Spec. Pubs. 3 and 9.

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By diamond-drilling 18 holes on coal deposits in the Coal Creek district, Gunnison County, Colorado, the Bureau discovered 3 minable coal beds varying in thickness from 3 feet 9 inches to 14 feet 10 inches. A preliminary estimate of reserves indicated 65,000,000 tons of coking coal and 35,000,000 tons of noncoking coal; a total of 100,000,000 tons of coal, of which 70 to 80 percent was considered recoverable. Carbonizing tests made by the Bureau disclosed that cokes from these coal beds were of metallurgical grade.

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   The recoverable reserves of coal are of the order of 8% of the total remaining resources. Natural geological conditions, as well as disturbances of the strata from previous mining operations, may combine to make unmineable coal seams that otherwise might be considered as potential reserves. Electric utility coal consumers are concerned about reliable supplies of coal at a minimum satisfactory heating value and sulfur content. Government involvement has caused uncertainties relative to the development of coal mining operations. Lack of coal development could have serious adverse impact on the future supply of coal.

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In examining the position of Illinois coal reserves and the future coal supply that may be needed from Illinois mines by 1985, the Illinois State Geological Survey mentions the slow progress in the development of synthetic fuels from coal as one factor that has limited the growth of Illinois coal resources. However, with ERDA's recent announcments of funding for Coalcon's 22 million cf/day demonstration plant to be constructed in New Athens, Illinois by 1980 and approval of planning funds for the Illinois coal gasification group's 18 million cf/day plant in Perry County, the impact of synthetic fuel production on Illinois coal should be significant before 1985. Looking at overall U.S. coal needs, the ISGS predicts that 102 million tons per year will be needed from Illinois mines by 1985.

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Illinois has the largest coal reserves of any state east of the Mississippi River, 161 billion tons, about seven-eighths of it accessible only by deep mining and one-eighth accessible only by surface mining. Illinois, however, is not as far down the road in the development of this resource as its sister states operating from a lesser base. It is fourth in coal production. Its industry mines about 60 million tons a year or 10% of the national production and trails West Virginia, Kentucky, and Pennsylvania. The industry obtains its tonnage from 57 mines, 21 underground and 36 surface. The underground mines average more than 1.5 million tons each for a total of 32 million, and the surface operations average about 800 thousand tons each, for a total production of 28 million. These figures indicate that Illinois differs from the national norm. Of

the 640 million tons produced countrywide, 290 million (45%) came from underground operations and 350 million (55%) from surface mines, an almost exact proportionate reversal of the Illinois figures. But Illinois does illustrate the trend east of the Mississippi. The big increase in surface mining production is coming and will come from the Rocky Mountain western regions.

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Surface mining accounts for nearly 50 percent of recent coal production in Illinois. In previous publications, the Illinois State Geological Survey reported that over 20 billion tons of coal in Illinois were potentially strippable; however, current economical and environmental issues associated with surface mining have created a need for estimates of the amount of strippable coal that can be recovered economically under present conditions. In estimating strippable reserves, the criteria used were (1) reliability of data, (2) overburden and coal thicknesses, (3) the size of the block of coal, and (4) proximity to man-made and natural obstacles. On the basis of the criteria, Illinois was determined to have 6 billion tons of surface-minable coal in the ground. This reserve is made up of 185 blocks of 6 million tons or more. The amounts of strippable reserves are large in western Illinois and especially in southwestern and southern Illinois, which are more attractive for surface mining because land costs are lower, the heating value of the coal is higher, and the tonnage recoverable per acre is greater. The southwestern and southern Illinois deposits are and will continue to be the major sources of surface-mined coal in the state; however, in view of current rates of production, the remaining reserves in this area are relatively small, and opportunities for new acquisitions and long-term development are limited. Only 38% of the strippable reserves mapped exceed 4 feet in thickness, and most of those reserves have overburden in excess of 50 feet.

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In this manual coal is discussed as an alternative energy source. Since technology for mining and burning coal already exists, coal may play a critical role during the coming transition period. Coal's increasing worth may spur a new era of mining in Iowa. Mining has been on the decline until recently, though Iowa coal has been mined for well over a century. New mines, if started, will most likely be strip mines because of economic considerations, but deep mines may ultimately be the source of most Iowa coal. Strip mines have denuded some areas in Iowa of vegetation and reduced their worth. New legislation has put that period behind us; even the old ravaged areas will be reclaimed. Iowa law makes coal mining a short term land use; after mining is completed the land will be restored and revegetated. Since most Iowa coal will not meet environmental standards for burning as it comes from the mine, research is needed to develop new ways and improve old methods of cleaning coal, so it may be burned safely. The Iowa coal project is building a pilot preparation plant at Iowa State University to remove pollutants from coal. The preparation plant is part of the research program that is studying all facets of Iowa coal from mining and reclamation to cleaning and burning.

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    Results are given of an investigation conducted by the Bureau of Mines to estimate known recoverable reserves of all coking coal in Pike County. Included is a brief resume of the chemical analysis of the coals and a table of estimated reserves as of January 1, 1948, for each coal bed in the county.

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4. Robertson, C. E., *Evaluation of Missouri's Coal Resources*, Report of Investigations No. 48, Missouri Geological Survey and Water Resources, Rolla, Missouri, 1971.

Missouri possesses coal resources of 31.7 billion tons as determined by mapping and exploration, ranking ninth among the states. Of this total, there are 2.1 billion tons of thick (greater than 42 inches) coal, 8.5 billion tons of intermediate thickness (28 to 42 inches), and 21.1 billion tons of thin (12 to 28 inches) coal. Remaining reserves, which total 10.4 billion tons, include 2.1 billion tons of thick coal, 5.0 billion tons of intermediate thickness, and 3.3 billion tons of thin coal. Remaining reserves are classified according to sulfur content. Data indicate that no significant areas of low-sulfur coal are present in Missouri. Approximately half of the state's coal reserve contains from 4 to 5 percent S, and one-fourth has from 3 to 4 percent S. Less than one-tenth contains less than 3 percent S and the remainder has more than 5 percent. An estimated additional possible coal resource of 18.2 billion tons is present in untested areas, giving a total coal resource of 49.9 billion tons.

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New estimates of Missouri's coal resources show total coal resources of 49 billion tons. Of this total, 12.3 billion tons is classed as a remaining reserve and 3.7 billion tons is a strippable reserve. Missouri possesses ample coal to support an expanded coal mining industry, according to new estimates. The immediate primary use of Missouri coal will continue to be for firing mine-mouth steam-electric power plants. Eventually, a more important use may be conversion to other fuels, including pipeline gas, solvent-refined coal, low-Btu gas, and liquid petroleum substitutes. Remaining reserves are classified according to sulfur content. Data indicate that no significant areas of low-sulfur coal are present in Missouri. Approximately half of the state's coal reserve contains from 4 to 5 percent S, and one-fourth has from 3 to 4 percent S. Less than one-tenth contains less than 3 percent S and the remainder more than 5 percent.

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Coal production in New Mexico increased rapidly from about 1880 to a peak of just over 4 million tons per year during World War I, then fell to a low of just over 116 thousand tons in 1958. Since then, production has increased very rapidly to a new high in 1973 of 9.3 million tons. Developments now in the planning stage would require nearly 75 million tons per year by 1983, and these plus other developments now being discussed could require production of as much as 110 million tons per year by that time. New Mexico's coal, nearly all of subbituminous or bituminous rank, is concentrated in the San Juan Basin and in the Raton Basin, with a number of smaller coal areas scattered over the state. The total coal resource within the state has been estimated at 282,877 million tons. Of that total only some 6000 million tons — just over 2% — are thought to be surface-minable now or in the near future. There are presently four major mines which are described. It would appear from preliminary work that surface-mined lands can be reclaimed successfully in New Mexico. Nearly all of the lands in the major strippable areas are of very low value at present; for example, the carrying capacity of the entire El Paso Natural Gas Co. lease, which will support two major gasification projects, has been estimated to be 735 sheep. Environmental matters are being considered extensively, and New Mexico's coal surface mining commission so far seems to be an efficient and even-handed agency for overseeing mine development. Unless additional surface mining is barred by federal environmental legislation, New Mexico's coal industry will become a major energy source for the southwestern United States, using only a tiny percentage of the state's total coal resource.

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   Strippable low-sulfur coal reserves in New Mexico and Colorado were studied to determine the location, quantity, quality, and economic position of coal in order to aid in national energy planning. Three major areas in the San Juan Basin contain high-volatile bituminous C rank coal with a sulfur content of 0.6% or less. There is a description of the area's geological structure and physiography, followed by summaries of 25 coal fields. While oil slightly outranks coal for current electric utility generation, it is estimated that by 1990 coal will outrank oil nearly two to one.

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North Dakota's coal reserves, part of the vast Fort Union Formation, are estimated at 350 billion tons or 22% of the U.S. total. Twenty-three counties have strippable lignites. Surface ownership of the land is divided between Federal (7.2%); Indian tribal lands (2.7%); and private, county, and municipal (87.5%). The Federal government, however, owns 20.2% of the subsurface land. Coal mines in 13 counties are already operating; and steam-electric generating plants are operating in seven counties, with three plants under construction. When construction is completed in 1980, generating capacity will have tripled over 1975 capacity. Four major coal companies produced 97.2% of the lignite in 1973. Electric generation is the major use of the state's coal and accounts for 84% of the coal produced. Future coal development may be used for export to other areas, production of more steam-generating plants, and synthetic fuels.

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The status of coal development in the three-state area is reviewed in regard to the energy situation. Estimated reserves are classified according to rank, sulfur content, and possible mining techniques. Differences and similarities in properties of lignite and subbituminous coals are characterized, and their influence on end use is discussed. Historical production patterns and recovery methods are summarized, and estimates of future production levels are presented. Problem areas in mining and land reclamation are discussed. Special emphasis is given to coal-fired electrical generating stations with respect to present operations, expansion plans, and problems related to combustion of low-rank fossil fuels. Plans for coal gasification complexes for production of substitute natural gas are discussed in relation to coal consumption, water usage, and environmental impact.

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The location and production potential of a large block for strippable reserves in North Dakota were determined by using published data as a base and adding new drill hole data or other data contributed by companies that presently own or lease coal lands. Only beds exceeding 5 feet in thickness, under less than 120 feet of overburden, and in large blocks of 5 million tons or more were included in the estimates. All such reserves are in the Fort Union Formation of western North Dakota and are lignite in rank. Sixteen large blocks of reserves evaluated in this study are estimated to contain a total of 4.1 billion tons of strippable lignite.

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   The recoverable reserves of the Pittsburgh (No. 8) coal in the Belmont field have been determined to be 1,340,052,875 tons. Calculations were made on a degree-of-reliability basis and were made separately for coal with 1000 feet or less of cover and for coal with greater than 1000 feet of cover. Mined and unmined areas were mapped on 7-1/2-minute topographic maps, and isopach and structure data for the Pittsburgh coal were added. Reliability categories were determined by distance from control points of measured coal thickness. A separate resource category was established for legal, civil, or economic restrictions. Calculations were based upon planimeter measurement.

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The eight billion tons of recoverable low sulfur anthracite coal underlying northeastern Pennsylvania are an energy reserve which should be developed to meet domestic energy needs. Production peaked in 1917 at 100 million tons and declined because of the shift to other fuels and mining economics, not from a lack of adequate reserves. Four coal fields make up Pennsylvania's anthracite region, which is the largest in the world. The geologic formations are such that development is challenging, but balanced by the suitability and proximity of anthracite coal for eastern metropolitan areas and the vastness of the reserves. The problems of establishing dependable markets, developing the technology for mining steeply inclined coal seams, and the need for a centralized mining program remain to be solved.

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Known reserves of coking coal in Marion County are estimated at 61 million short tons and known recoverable reserves 28 inches or thicker at 34 million tons. Included are carbonizing properties and tables of estimated reserves and washing characteristics.

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Known reserves of coking coal in Scott County are estimated at 143 million short tons and known recoverable reserves 28 inches or thicker at 39 million tons. Included are tables of estimated reserves and washing characteristics.

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Known reserves of coking coal in the Sewanne seam in Sequatchie County are estimated at 76 million short tons and known recoverable reserves 28 inches or thicker are estimated at 31 million short tons. Included are carbonizing properties and tables of estimated reserves and washing characteristics.

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The Southern Tennessee coal field comprises some 14,000 square miles of the Cumberland Plateau physiographic province and includes all or parts of 11 counties. The coal measures belong to the lower Pennsylvanian system. The largest coal potential lies with the Richland and Sewanee seams, which are contained in the Whitwell shale. The methods of obtaining coal reserves data in this report are adaptations of those used by the Tennessee Division of Geology, U.S. Bureau of Mines, and U.S. Geological Survey. This study differs from previous coal reserve estimates in that emphasis is placed on recoverable underground reserves as well as strippable reserves. Conservative premises were used throughout this study so that the resulting reserve figures may be considered as the minimum known recoverable coal reserves. Therefore, the total known recoverable

reserves of coal in the Whitwell shale in southern Tennessee as of January 1, 1979, are 377,385,000 tons based on the above criteria considered with recovery factors of 50% for underground mining and 80% for strip mining. The Sewanee seam contains the largest part of these reserves, totaling 312,665,000 tons. The largest reserves in any southern Tennessee county are in Sequatchie County with 86,580,000 tons. The reserves in this area are ample for the future, and are much larger than previously estimated.

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   Strippable deposits are close to the two major metropolitan areas, making lignite an attractive potential fuel for electrical generation and for industrial use. Lignite is perceived by policymakers and the public as a transition for use between depletion of oil and gas reserves and commercialization of renewable energy sources. Main economic and regulatory forces are systematically examined to develop growth estimates. Various alternatives in sources of energy, regulatory requirements, and uses are reviewed. For the nominal case scenario, a tenfold increase in production by 2000 AD to approximately 200 MTY was forecast, which implied a commitment of 6.0 billion tons of the estimated 6.7 billion ton reserve. Other scenarios are developed and key policy issues reviewed.

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The Wasatch Plateau of Central Utah is economicaly important because it contains large coal reserves. Rocks in the southern part of the Wasatch Plateau coal field are early to late Cretaceous, lower Coloradoan, to late Paleocene in age. The Hiawatha and Upper Hiawatha coal seams of the Blackhawk Formation are thick and extensive. The Hiawatha is about 1.8 meters (6 feet) thick, while the Upper Hiawatha averages 4.2 meters (14 feet) thick and is probably minable throughout the study area except south of Convulsion Canyon. The coal is high-volatile C bituminous of noncoking quality. It is low sulfur, low ash, and contains abundant resin. Mining in the Wasatch Plateau has been continuous since 1875, and over 112 million tons of coal have been produced.

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The area covered in this report is a 200-square-kilometer area located along the southern margins of the Kaiparowits Plateau. The extensive outcrops and a data base of more than 200 drillholes completed on a 400-meter spacing grid provide the major data used to complete the information presented in this article. Outcrop mapping and tracing of individual units along the outcrops provided a good understanding of the lateral continuity of the coal-bearing units and allowed greater confidence in correlating from drillhole to drillhole than would have been realized if only drillhole data were available. Close-spaced drilling has delineated the presence of six major coal seams that locally are subdivided by rock splits into as many as eleven minable seams. Isopach maps of the coal seams and rock intervals between seams and paleochannel maps have been prepared for all units within the 75-meter-thick coal zone to show the value of a knowledge of depositional environments and differential compaction in predicting the location of minable coal seams and areas of suitable mining conditions. Paleochannel sandstones that overlie coal seams may significantly affect the mining that occurs in the coal seams. Differential compaction in sediments that laterally interfinger with paleochannel sandstones may result in unstable roof conditions and cause the development of rolls and compactional thinning of coal seams. Mining activities may be hampered by sporadic influxes of water from the roof in areas where perched water tables in paleochannel sandstones are disrupted by mining.

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Sandia Laboratories, Lawrence Livermore Laboratory, and the Laramil Energy Technology Center participated in a U.S. Department of Energy funded program to select and characterize a potential underground coal gasification test site in the state of Washington. A site in the Centralia-Chehalis coal district, satisfying certain criteria, was selected for characterization. The characterization procedures included surface and borehole techniques and hydrology tests. Geologic structure and coal seam structure and continuity were determined using surface geophysical prospecting (logging and cross-borehole, inseam seismic) techniques. A complete set of geophysical logs was taken in eight exploratory boreholes to determine lithology and properties of the coal and surrounding strata. Coal cores taken from four different exploratory boreholes were analyzed to determine coal quality. Results of the characterization show that the coal seam of interest is approximately 47 ft thick at a depth of 570 to 600 ft at the site. The seam is characterized by high ash content, relatively low overall heating value, and a low permeability. The site appears suitable for conducting an underground coal gasification test.

2. Beikman, H. M., Gower, H. D., Dana, T. A. M., *Coal Reserves of Washington,* Washington Division of Mines and Geology Bull. 47, 1961, 115 pp.

3. Livingston, V. E., Jr., "Coal in Washington," in *Energy Resources of Washington,* Washington Division of Geology and Earth Resources Inf. Circ. 50, 1974, pp. 39-62.

4. Moen, W. S., *Mines and Mineral Deposits of Whatcom County, Washington,* Washington Division of Mines and Geology Bulletin, 57, 1969.

5. Morris, D. J., Ames, P. R., *Additional Coal Resources in the Green River District, King County, Washington,* presented at the 1980 Pacific Northwest Metals and Minerals Conference, May 7-9, 1980, Seatle, Wash., John T. Boyd Company, Denver, Colo., 1980.

6. Vine, J. D., *Geology and Coal Resources of the Cumberland, Hobart, and Maple Valley Quadrangles, King County, Washington,* U.S. Geological Survey Professional Paper 624, 1969.

7. Vonheeder, E. R., "Coal Exploration on State-Administered Lands in Whatcom and Skagit Counties During 1976," *Washington Geologic Newsletter,* Vol. 5, No. 1, 1977.

WEST VIRGINIA

1. Babu, S. P., Barlow, J. A., *Suitability of West Virginia Coals to Coal-Conversion Processes*, W. VA, Geol. Econ. Surv., Coal-Geol. Bull. No. 1, 1973, pp. 1-32.

Properties of West Virginia coals are shown on a series of maps, with recoverable reserves estimates at 58 billion tons. Processes including combustion, low-Btu gasification, high-Btu gasification, liquefaction, and carbonization are discussed with reference to properties of the coals and five different coal conversion processes.

2. Barlow, J. A., *Coal and Coal Mining in West Virginia*, West Virginia Geological and Economic Survey Coal-Geology Bull. 2., 1974, 63 pp.

3. Dowd, J. J., and others, *Estimate of Known Recoverable Reserves of Coking Coal in Brooke County, West Virginia*, Report of Investigation 5160, U.S. Bureau of Mines, 1955.

4. Dowd, J. J., and others, *Estimate of Known Recoverable Reserves of Coking Coal in Marshall County, West Virginia*, Report of Investigation 5207, U.S. Bureau of Mines, 1955.

5. Dowd, J. J., and others, *Estimate of Known Recoverable Reserves of Coking Coal in Ohio County, West Virginia*, Report of Investigation 5171, U.S. Bureau of Mines, 1955.

6. Dowd, J. J. and others, *Estimate of Known Recoverable Reserves of Coking Coal in Raleigh County, West Virginia*, Report of Investigation 4893, U.S. Bureau of Mines, 1952.

7. Englund, D. K., Windolph, J. F., Jr., *Availability of Low-Sulfur Coal in Greenbrier County, West Virginia*, Open-File Report, U.S. Geological Survey, 1972.

8. Englund, K. J., *Availability of Low-Sulfur Coal in McDowell County, West Virginia*, Open-File Report, U.S. Geological Survey, 1972.

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12. Hadley, D. G., *Availability of Low-Sulfur Coal in Clay County, West Virginia*, Open-File Report, U.S. Geological Survey, 1972.

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15. Headlee, A. J. W., Nolting, J. P., Jr., *Characteristics of Minable Coals of West Virginia,* West Virginia Geological Survey Rept. v. 13, 1940.

16. Mory, P. C., Brocoum, A. V., Beers, A. H., *Coal Reserve Study, New River Gorge, West Virginia,* Open-File Report, Bureau of Mines, Pittsburgh, PA, Eastern Field Operation Center, March, 1977, 39 pp.

The report is an appraisal of coal reserves in the New River Gorge area of West Virginia. It contains a description of the minable coalbeds in the area, an assessment of their reserves, and a study of the feasibility of mining from entries outside proposed boundaries of either a wild and scenic river area or a national park.

17. Provost, J. M., Dowd, J. J., Abernethy, R. F., Reynolds, D. A., *Estimate of Known Recoverable Reserves of Coking Coal in Marion County, West Virginia,* Bureau of Mines, Pittsburgh, PA, BM-RI-5267, 1956.

18. Repine, T., "Coal Thickeners: What You See May Not Be What You Get," in 1981 *Mountain State Geology,* West Virginia Geological and Economic Survey.

Discusses recoverability of coal seams and compares seam height and mining height.

19. Reppert, R. S. and Repine, T., "West Virginia's Coals: How Much and Where?," in 1980 *Mountain State Geology,* Publication MSG-80, West Virginia Geological and Economic Survey.

This article examines the necessary procedures in determining the actual tonnage of coal in an area and includes an explanation of how it is used.

20. Skelly and Loy, *Map of West Virginia and Maryland Coal Mine Locations*, Coal Age Mining Informational Services, New York, N.Y., 1980.

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Known reserves of coking coal in McDowell County are estimated at 2,216,691,000 short tons, and known recoverable reserves 28 inches and more thick are estimated at 1,074,722,000 short tons. Report includes table of estimated reserves as of January 1, 1951 for each of the coal beds.

26. Wallace, J. J., Dowd, J. J., Tavenner, W. H., Provost, J. M., Abernethy, R. F., Reynolds, D. A.. *Estimate of Known Recoverable Reserves of Coking Coal in Mercer County, W. Virginia.* Bureau of Mines, Washington, D.C., BM-RI-5077, 1954.

27. Wallace, J. J., Dowd, J. J., Tavenner, W. H., Abernethy, R. F., Reynolds, D. A., *Estimate of Known Recoverable Reserves of Coking Coal in Mingo County, W. Virginia,* Bureau of Mines, Pittsburgh, PA, BM-RI-5068, 1954.

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Known reserves of coking coal in Wyoming County are estimated at 2,669,432,000 short tons, and known recoverable reserves 28 inches and more thick are estimated at 1,166,567,000 short tons. Report includes table of estimated reserves as of January 1, 1951 for each of the coal beds.

29. Welker, D. B., Kasales, S., Hilgar, G., Peck, M., *Surface Mines in West Virginia as of April 1, 1980,* West Virginia Geological and Economic Survey Pub. MB-2, 1980, 48 pp.

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Presents an overview of methods used by West Virginia Geologic and Economic Survey to identify and determine West Virginia coal reserves.

WYOMING

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   Maps at scales of 1:4,000 and 1:8,000 showing various classes of ownership, available colored and uncolored.

2. Berryhill, H. L., Jr. and others, *Coal Resources Map of Wyoming*, Coal Investigations Map C-6. U.S. Geological Survey, 1951.

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4. Breckenridge, R. M. and others, *Campbell County, Wyoming: Geologic Map Atlas and Summary of Land, Water, and Mineral Resources*, County Resource Series 3, Geological Survey of Wyoming, 1974.

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8. Denson, N. M., Keefer, W. R., Horn, G. H., *Coal Resources of the Gillette Area (Campbell County), Wyoming*, Miscellaneous Geologic Investigation Map I-848-C, U.S. Geological Survey, 1973.

9. Glass, G. B., Jones, R. W., *Bibliography of Wyoming Coal*, The Geological Survey of Wyoming Bull. 58, 1974.

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11. Glass, G. B., Roberts, J. T., *Coals and Coal-Bearing Rocks of the Hanna Coal Field, Wyoming*, The Geological Survey of Wyoming, Report of Investigations No. 22, 1980.

12. Glass, G. B., Roberts, J. T., *Remaining Strippable Coal Resources and Strippable Reserve Base of the Hanna Coal Field in Southcentral Wyoming*, Reports of Investigations No. 17, 1979.

It is estimated that 674.31 million tons of strippable coal resources remain in four newly defined mining districts of the Hanna Coal Field in south central Wyoming. Of these strippable resources, 46% or 309.97 million tons lie between 0 to 100 feet of cover while the other 54% or 364.34 million tons lie between 100 to 200 feet of cover. The remaining strippable reserve base, or that part of the strippable resources from which strippable reserves are derived, is reduced to 648.29 million tons (96% of strippable resources). Forty-six percent or 297.12 million tons of the reserve base occur under less than 100 feet of cover while the remaining 351.17 million tons occur under thicker cover (100 to 200 feet thick). Although strippable reserves per se (recoverable reserves) were not estimated, a fair approximation is that strippable reserves equal at least 80% of the reserve base between 0 to 100 feet deep or 237.7 million tons. Although some percentage of the reserve base between 100 to 200 feet deep is also recoverable, the percentage is harder to estimate. Applying the same rule of thumb that strippable reserves may equal 80% of that tonnage as well, another 280.94 million tons of reserves is identified for a total of 518.64 million tons of strippable reserves in the Hanna Coal Field. A more conservative appraisal of strippable reserves in the 100 to 200 feet depth range is half the reserve base or 175.59 million tons, thus reducing the remaining reserves to 413.29 million tons. With the exception of 9.44 million tons of strippable bituminous resources in the 0 to 100 feet overburden category and another 6.65 million tons in the 100 to 200 feet overburden category, all the strippable resources and strippable reserve base in the Hanna Coal Field are of sub-bituminous rank.

13. Glass, G. B., *Review of Wyoming Coalfields, 1975*, The Geological Survey of Wyoming, 1975.

14. Glass, G. B., *State-Owned Coal Lands in Wyoming*, Public Information Series 2, Wyoming Geological Survey, Laramie, 1976.

The Federal Government owns approximately 46 percent of the coal lands in Wyoming and is the largest single mineral owner. The private sector, which includes the Union Pacific Railroad, utilities, corporations, and individual citizens, is the next largest owner class with 41.5 percent, followed by the Indians (7.5 percent) and the State of Wyoming (5 percent). Wyoming has retained mineral rights under at least three million acres of the 4.2 million acres of state land. Of these three million acres, 1.3 million acres are underlain by coal, with about 1.2 million acres under lease. Most state lands are limited to one or two isolated sections per township. Large, continuous blocks of state coal land are common only in Johnson,

Sheridan and, to a lesser degree, Converse counties. The quantity and quality of coal resources beneath state land is very poorly defined. Similarly, detailed resource information, including quantity and quality, is lacking for all but one or two of the state coal leases. Two recent resource estimates suggest that the total coal resources underlying state-owned coal land may be on the order of 32 to 58 billion tons, with 13 to 16 billion tons of that recoverable by surface and/or underground mining techniques.

15. Glass, G. B., *State-Owned Coal Lands in Wyoming*, Public Information Series 2, NP-24083, The Geological Survey of Wyoming, Laramie, WY, 1979.

Wyoming has retained mineral rights under at least three million acres of the 4.2 million acres of state land. Of these three million acres, 1.3 million acres are underlain by coal with about 1.2 million acres under lease. There are, however, no small scale mineral ownership maps that accurately depict the location of all state coal lands for leases. Accurate locations must come from records and plats in county and state offices. Most state lands are limited to one or two isolated sections per township. These are usually the state school sections 16 and 36. In some cases, other sections have been substituted. Large, contiguous blocks of state coal land are common only in Johnson, Sheridan and, to a lesser degree, Converse counties. The quantity and quality of coal resources beneath state land is very poorly defined. Similarly, detailed resource information, including quantity and quality, is lacking for all but one or two of the state coal leases. Two recent resource estimates suggest that the total coal resources underlying state-owned coal land may be on the order of 32 to 58 billion tons, with 13 to 16 billion tons of that recoverable by surface and/or underground mining techniques. Presently, state coal lands lease for 50 cents an acre for the first five years and $1.00 an acre for the sixth through tenth year or renewal thereof. Production of coal from state leases has always been small. Royalties on old leases will remain at 7% of the gross output until the lease is renewed. Leases with commercial discoveries of coal rent for $1.00 an acre, but these are actually advance royalty payments and are reported as royalties. Over the past 5 years, royalty collections, including advance royalties, have fluctuated from $3300 in 1971 to $250,132.69 in 1973.

16. Glass, G. B., "Update on the Powder River Coal Basin," in *Geology and Energy Resources of the Powder River*, Laudon, R. B., Curry, W. H. III, Runge, J. S. (eds.), Annual Field Conference of the Wyoming Geological Association Casper, WY, September 1976, pp. 209-220.

Although coals are reported in the upper cretaceous Mesaverde and Lance formations, the thickest and most important coals are limited

to the Paleocene Fort Union Formation and the Eocene Wasatch Formation. Since Berryhill et al.'s (1950) original resource estimates, the U.S. Geological Survey has estimated that another 500 billion tons of undiscovered resources underlie the Powder River Basin. These hypothetical and speculative resources, however, will soon move into the identified category.

17. Glass, G. B., "Wyoming Coal Deposits," in *Geology of Rocky Mountain Coal,* Murray, D. K. (ed.), Golden, CO, 26 April 1976, CONF-7604140, 1977, pp. 73-84.

18. Glass, G. B., *Wyoming Coal Fields, 1978*, Public Information Circular No. 9, NP-24078, The Geological Survey of Wyoming, Laramie, WY, 1978.

When an estimate of the resources of the previously ommitted 53.46% of the state's coal-bearing land is added to the mapped and explored estimate, the U.S. Geological Survey estimates that Wyoming's original resources under less than 3000 ft of overburden will increase to 836,891,430,000 tons. Wyoming's original resource figure becomes 936,891,430,000 tons when the overburden category is extended to 6000 ft [Averitt, 1975 (listed under "General Sources")]. In the 0 to 6000 ft overburden category, Wyoming has the largest in-place coal resources in the nation. Estimates of Wyoming's original in-place coal resources by major coal-bearing region and by county are given in tables. The original resources in these tables include mapped and explored bituminous coals 14 in. or greater in thickness and subbituminous coals 2.5 ft and thicker. Measured, indicated, and inferred categories are combined; overburden limits for these figures are 0 to 3000 ft. Coal production is reported by county. Wyoming's known strippable reserve base of subbituminous coal is shown in Table 9. This strippable reserve base is limited to a few mapped and explored areas and is only a small portion of Wyoming's potentially strippable coal, which could easily total ten times the known reserve base.

19. Glass, G. B., *Wyoming Coal Production and Summary of Coal Contracts,* The Geological Survey of Wyoming Public Inf. Circ. 12, 1980.

20. Grazis, S. L., *Geologic Map and Coal Resources of the Gap SW Quadrangle, Campbell County, Wyoming,* U.S. Geological Survey Coal Investigations Map C-78, 1977.

21. Grazis, S. L., *Geologic Map and Coal Resources of the Saddle Horse Butte Quadrangle, Campbell County, Wyoming,* U.S. Geological Survey Coal Investigations Map C-79, 1977.

22. Grazis, S. L., *Geologic Map and Coal Resources of the Scraper Reservoir Quadrangle, Campbell County, Wyoming,* U.S. Geological Survey Coal Investigations Map C-77, 1977.

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24. Haddock, D. R., Kent, B. H., Bohor, B. F., *Geological Map and Coal Sections of the Croton Quadrangle, Campbell County, Wyoming,* U.S. Geological Survey Miscellaneous Field Studies Map MF-826, 1976.

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26. Mapel, W. J., Dean, B. W., *Preliminary Geologic Map and Coal Sections, Ulm Quadrangle, Sheridan County, Wyoming,* U.S. Geological Survey Miscellaneous Field Studies Map MF-731, 1976.

27. Mapel, W. J., Malahy, M. D., *Geologic Map and Coal Sections of the Buffalo Run Creek Quadrangle, Sheridan County, Wyoming,* U.S. Geological Survey Miscellaneous Field Studies Map MF-792, 1976.

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29. Mapel, W. J., *Geologic Map and Coal Sections of the Bar N Draw Quadrangle, Wyoming and Montana,* U.S. Geological Survey Miscellaneous Field Studies Map MF-763, 1976.

30. Mapel, W. J., *Geology and Coal Resources of the Buffalo — Lake De Smet Area, Johnson and Sheridan Counties, Wyoming,* U.S. Geological Survey Bulletin 1078, 1959.

31. Martin, G. C., *Coal Development Map of the Little Thunder Reservoir Quadrangle, Campbell County, Wyoming,* Open-File Report 77-58, U.S. Geological Survey, 1977.

32. Masursky, H., *Uranium-Bearing Coal in the Eastern Part of the Red Desert Area, Wyoming,* U.S. Geological Survey Bulletin 1099-B, 1962.

33. Olive, W. W., *The Spotted Horse Coalfield, Sheridan and Campbell Counties, Wyoming,* U.S. Geological Survey Bulletin No. 1050, 1957, 83 pp.

34. Osterwald, F. W., and others, *Mineral Resources of Wyoming,* Bulletin 50, Wyoming Geological Survey, 1959.

35. Parsons, F. W., "The Coal Mining Situation in Northern Wyoming," *Engineering and Mining Journal,* Vol. 84, 1907, pp. 930-935.

36. Pipiringos, G. N., *Uranium-Bearing Coal in the Central Part of the Great Divide Basin,* U.S. Geological Survey Bulletin No. 1099-A, 1961.

37. Shown, L. M., *Land Use Map of the Gillette Area, Wyoming, 1970,* Geologic Investigations Map 848-A, U.S. Geological Survey, 1973.

38. Smith, J. B., Ayler, M. F., Knox, C. C., Pollard, B. C., *Strippable Coal Reserves of Wyoming: Location, tonnage, and characteristics of coal and overburden,* U.S. Bureau of Mines, Washington, DC, BM-IC-8538, 1972.

Coal resource data from published sources and company files were used by the Bureau of Mines to determine the location and extent of strippable coal reserves in Wyoming. Total strippable reserves of 23 billion tons were estimated in seven major coal areas. Seven large strip mining operations were active in 1969. Cutoffs used to define strippable reserves were (1) minimum coalbed thicknesses of 5 feet; (2) overburden-to-coal ratios of less than 10 cubic yards of overburden per ton of coal, and (3) total overburden thicknesses of less than 120 feet, except where reserves occur in multiple beds or a single thick bed. Tertiary rocks along margins of the Powder River Basin contain most of the strippable coal reserves in Wyoming. The Wyodak beds ranging in combined thickness from 30 to 130 feet, drop out on the east flank of the basin and contain an estimated 19 billion tons of strippable subbituminous C-rank coals under less than 200 feet of overburden. Partings between these beds total less than 60 feet. The 100- to 200-foot-thick Healy bed on the western flank of the basin and the 35-foot-thick School and 20-foot-thick Badger beds on the south also contain large, strippable reserves. Elsewhere in Wyoming, strippable deposits are subbituminous coal of late Cretaceous and tertiary ages, mostly in the Hanna and Great Divide Basins in the South-Central portion of the state and in the Kemmerer-Hamms Fork Region in the southwestern corner.

39. U.S. Geological Survey. *Land and Coal Ownership in the Gillette Area, Wyoming,* Miscellaneous Geologic Investigations Map 848-B, U.S. Geological Survey, 1973.

40. Waring, J., *Preliminary Coal Resource Occurrence Map of the Wyodak Bed in the Gap SW Quadrangle, Campbell County, Wyoming,* Map, U.S. Geological Survey, 1976.

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